





# EACVI survey on evaluation and quantification of aortic regurgitation by multi-modality imaging

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## Abstract

### Aims

To investigate the real-world, current clinical practice of the assessment and management of aortic regurgitation (AR).

### Methods and results

An electronic survey was distributed to cardiovascular imaging specialists by the European Society Association of Cardiovascular Imaging Scientific Initiatives Committee. Three hundred respondents from 66 countries completed the survey. In patients where initial qualitative evaluation suggested moderate AR, regurgitation severity was further characterized using vena contracta in 83%, pressure half-time in 70%, jet width/outflow tract diameter in 59%, regurgitant volume/effective orifice area 57% and three-dimensional vena contract in 20% of respondents. Cardiac magnetic resonance (CMR) was used by 72% of respondents when transthoracic echocardiographic (TTE) image quality was poor

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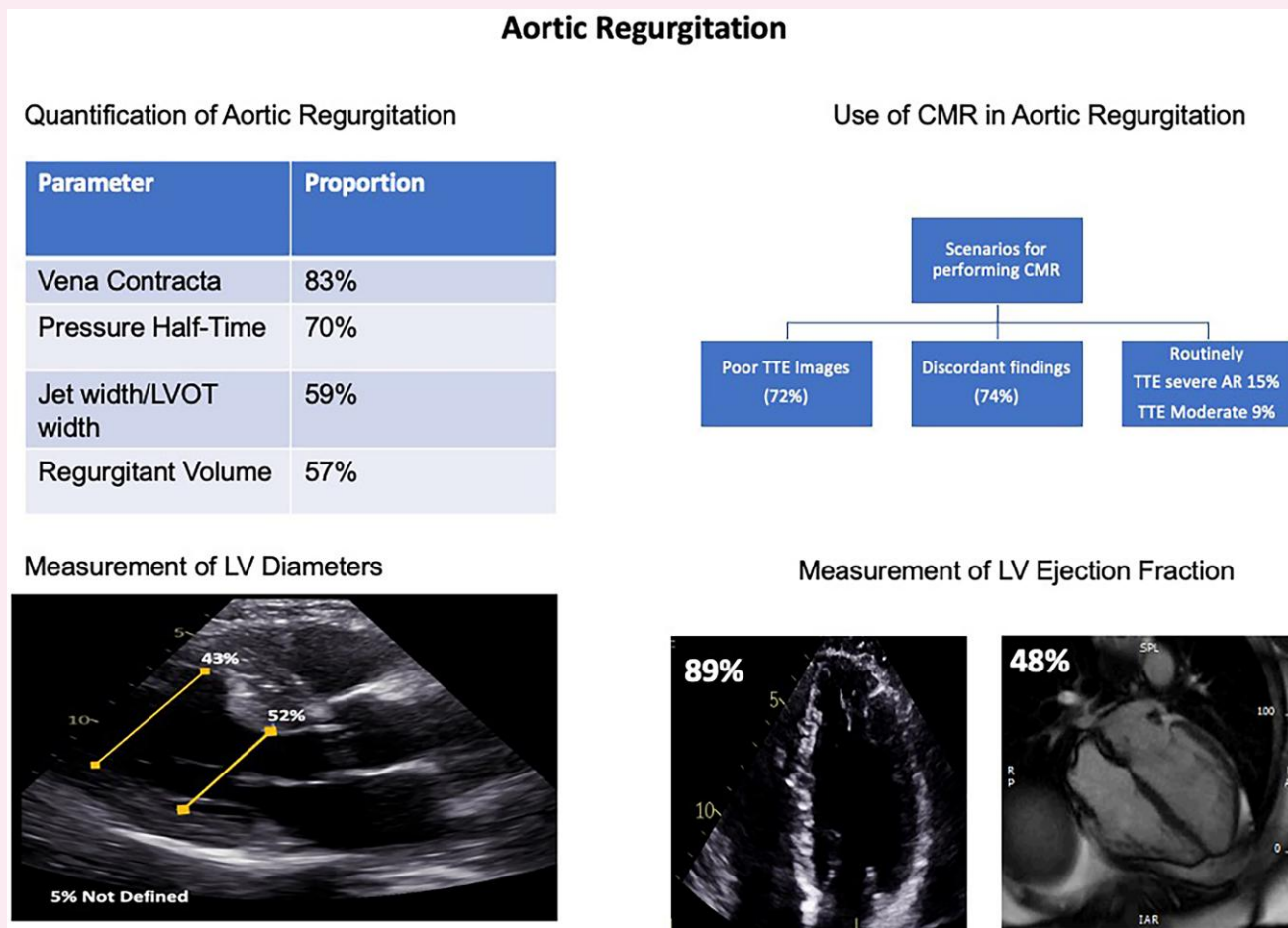
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and 74% of respondents when there was discordance between Doppler findings and ventricular assessments. CMR 4-dimensional flow was performed by 19% of respondents. Left ventricular (LV) diameters were measured at the mitral valve level by 52% and at the mid LV by 43% of respondents. LV volumes were measured using TTE by 70%, with CMR by 40% and with CT by 2% of respondents.

## Conclusion

There is heterogeneity in the echocardiographic methods used to quantify AR. The vena-contracta is the most commonly used for assessment of AR severity with relative underutilisation of quantitative methods. CMR is widely used to assess AR severity when echocardiographic assessments are uncertain. There is variation in the anatomical location to measure LV dilatation and variable use of LV volumes which may impact decision making for intervention.

## Graphical Abstract



AR, aortic regurgitation; CMR, cardiac magnetic resonance; LV, left ventricle; LVOT, left ventricular outflow tract; TTE, transthoracic echocardiogram.

## Keywords

aortic regurgitation • echocardiography • cardiac magnetic resonance • quantification • remodelling • left ventricle

## Introduction

Aortic regurgitation (AR) is found in up to 15% of the general population.<sup>1</sup> Common causes include degenerative aortic valve disease, bicuspid aortic valve, rheumatic heart disease, infective endocarditis, inflammatory disorders, and abnormalities of aorta.

Significant AR leads to progressive enlargement of the left ventricle (LV), eccentric hypertrophy and eventually systolic impairment.<sup>2</sup> International guidelines recommend aortic valve intervention in patients with severe AR with symptoms or in asymptomatic patients with impaired

LV systolic function (ejection fraction < 50%) or increased end-systolic diameters (>50 mm) as these are associated with poor prognosis.<sup>3</sup> More recently, lower thresholds for intervention and the use of LV volumes have been proposed as better predictors of outcome.<sup>4,5</sup>

Quantification of AR is commonly assessed using echocardiography and can be performed using a range of different methods including qualitative, semi-quantitate and quantitative measurements. An integrated approach is recommended as each individual parameter has limitations.<sup>6</sup> However, quantification of regurgitant volume and effective regurgitant orifice area, where possible, is

recommended as they provide better risk stratification than qualitative or semi-quantitative methods.<sup>7</sup> Transoesophageal echocardiography (TEE) may be helpful where image quality using transthoracic echocardiography (TTE) is limited.

Echocardiographic assessment of AR may be inconclusive or difficult, particularly where there are multiple or eccentric jets. Cardiac magnetic resonance (CMR) can be useful in these situations. Several CMR based methods for quantification of AR exist.<sup>8</sup> In addition, CMR imaging can accurately quantify LV volumes as well as identify myocardial scar.<sup>9</sup>

The objective of the survey is to investigate current practice for assessing the aetiology of AR, its severity and its impact on the left ventricle using multi-modality imaging.

## Methods

### Survey design and population

An electronic survey was designed by the European Association of Cardiovascular Imaging (EACVI) Scientific Initiatives Committee. After the initial survey was created, the committee reviewed and amended the questions to ensure clarity and consistency. The survey was administered via an electronic platform over a 2 month period from 6 November 2024 to 6 January 2025. All respondents were anonymous. The survey was disseminated via EACVI website and EACVI newsletter emails and social media. Data was collected on the methods used to assess symptoms, aetiology and quantify AR, LV size and function and aortic dimensions.

The survey was divided into the following sections:

- (1) Demographics and characteristics including age, gender, institution type, speciality.
- (2) Echocardiographic methods used to assess AR severity including qualitative (jet width/LV outflow tract width), semi-quantitative (vena contracta, pressure half-time) and quantitative measurements (regurgitant volume, effective orifice area).
- (3) Methods used to quantify AR where TTE is inconclusive.
- (4) Methods used to assess LV size and function [TTE, CMR, Computed tomography (CT)].
- (5) Availability and use of TEE, stress echocardiography and CMR in patients with AR.
- (6) Imaging modalities used to assess co-existent aortic pathology.

### Statistics

Descriptive data are reported as numbers or percentages.

## Results

There were 300 participants from 66 countries. Two hundred and nineteen of the 300 (73%), 17/300 (5.7%), 10/300 (3.3%), 19/300 (6.3%), 25/300 (8.3%), 8/300 (2.7%), 2/300 (0.7%) were based in Europe, South America, North America, Asia, the Middle East, Africa and Australia, respectively. One hundred and forty-one of the 300 (47%) were female, whilst 115/300 (38%) were under 40 years old, 110/300 (37%) between 40 and 49 years old, 43/300 (14%) between 50 and 59 years old and 32/300 (11%) over 60 years old. Respondents were based in tertiary, secondary and primary care centres in 202/300 (67%), 78/300 (26%), and 20/300 (7%), respectively.

### TTE quantification of AR

#### Semi-quantitative parameters

Vena contracta width was the most commonly used semi-quantitative measurement, used by 202/296 (68%), 245/296 (83%), and 236/296 (80%) of the respondents where initial qualitative assessment was mild, moderate, or severe, respectively (Figure 1).

Pressure half-time was the next most used measure, employed by 194/296 (66%), 208/296 (70%), and 203/296 (69%) of the respondents where initial qualitative assessment was mild, moderate, or severe, respectively.

Jet width/LV outflow diameter was measured by 150/296 (51%), 174/296 (59%), and 175/296 (59%) of the respondents where initial qualitative assessment was mild, moderate, or severe, respectively.

Flow reversal in the descending aorta was measured by 131/296 (44%), 240/296 (81%), and 241/296 (81%) of respondents where the initial qualitative assessment was mild, moderate or severe, respectively. Flow reversal in the abdominal aorta was measured by 63/296 (21%), 135/296 (46%), and 150/296 (51%) of respondents where the initial qualitative assessment was mild, moderate or severe, respectively.

#### Quantitative parameters

Two-dimensional regurgitant volume and effective regurgitant orifice area were measured by 84/296 (28%), 170/296 (57%), and 182/296 (61%) of respondents where initial qualitative assessment was mild, moderate or severe, respectively.

Three-dimensional vena contracta was measured by 37/296 (13%), 59/296 (20%), and 68/296 (23%) of respondents where initial qualitative assessment was mild, moderate or severe, respectively.

### Transoesophageal echocardiography

TEE would be used by 175/291 (60%) of respondents if there was discordance between clinical findings and TTE quantified AR severity, 200/291 (69%) used TOE if TTE image quality was poor and 119/291 (41%) used TEE where the mechanism of AR was not clear from the TTE. When there was suspected infective endocarditis and AR was present, 222/291 (76%) used TEE. Routine TEE was used in all patients with moderate and severe AR by 35/291 (12%) and 104/291 (36%) of respondents, respectively.

### Stress echocardiography

Exercise stress echocardiography was used to assess exercise-induced symptoms in asymptomatic patients with severe AR by 101/289 (35%) of respondents, and to assess contractile reserve in 77/289 (27%) of respondents. Treadmill exercise without echocardiography was used to assess symptoms by 45/289 (16%) of respondents.

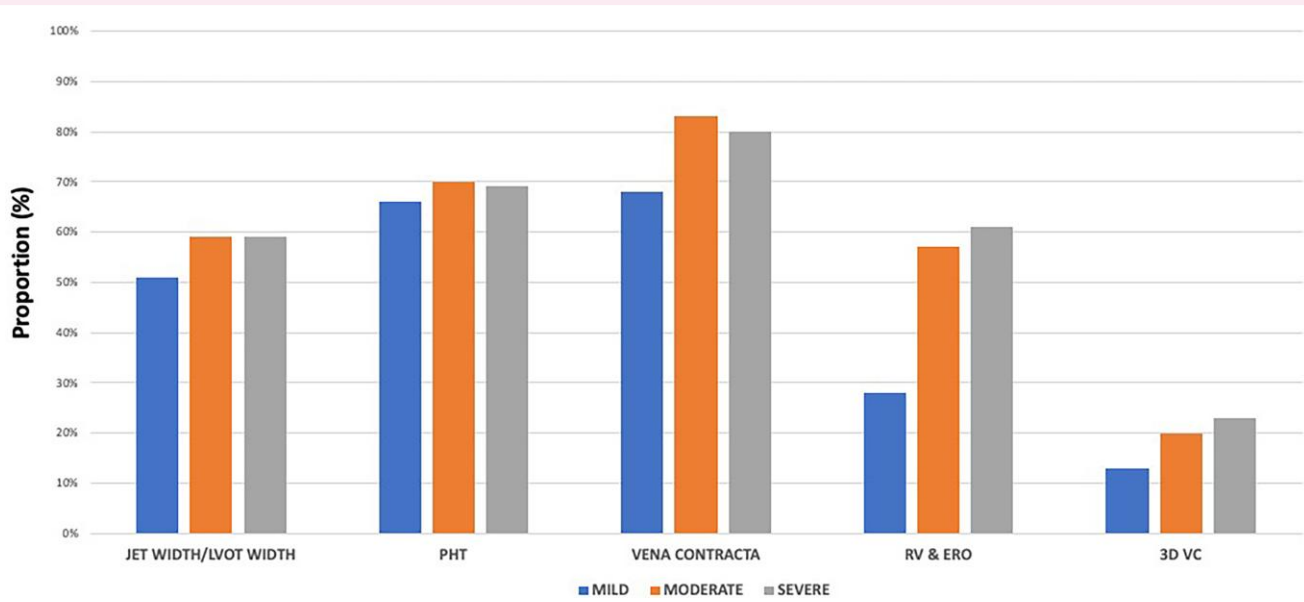
### CMR imaging

Seventy-two percent (203/282) of respondents would use CMR if TTE image quality was poor. Of respondents 50 years and older, 48/75 (64%) would use CMR if TTE image quality was poor compared with 155/207 (75%) of respondents under 50 years old. 210/282 (74%) of respondents would use CMR if there was discordance between Doppler findings and ventricular assessment (e.g. ventricular enlargement greater than expected for degree of AR), and 197/282 (70%) would use CMR where there was discordance between clinical findings and echocardiographic findings. 43/282 (15%) of respondents used CMR in all cases where severe AR was identified by TTE and 25/282 (9%) where moderate AR was identified by TTE.

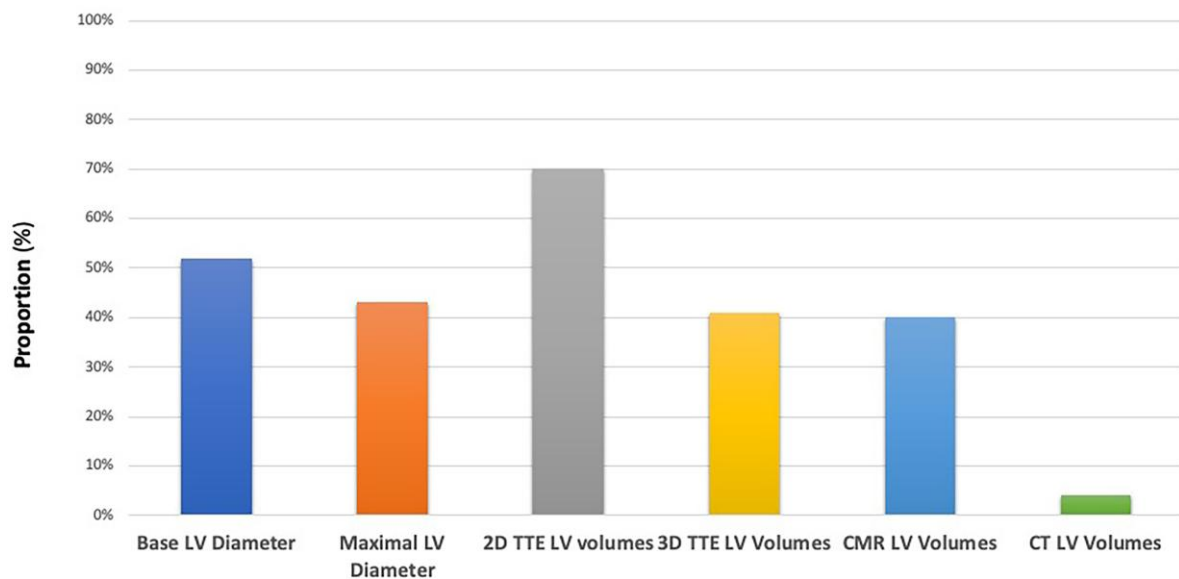
The most common method to calculate regurgitant volume and fraction using CMR was direct diastolic reverse volume at aortic root with phase-contrast flow imaging 170/253 (67%). Indirect assessment based upon LV stroke volume—RV stroke volume was used by 128/253 (51%), whilst 93/253 (37%) assessed [aortic total forward stroke volume (SV)]—(pulmonary artery total forward SV) (37%). 4D flow sequences were performed by 48/253 (19%) of respondents.

### Assessment of LV remodelling

LV diameters were measured on TTE at the mitral valve level by 154/298 (52%) of respondents whilst they were measured at the mid



**Figure 1** Proportion of respondents who used each different echocardiographic methods to quantify AR according to initial qualitative evaluation.



**Figure 2** Proportion of respondents who use each different methods to quantify LV dilatation.

ventricle level by 129/298 (43%) of respondents and 15/298 (5%) did not define the location. Two-dimensional LV volumes were measured by 210/298 (70%) of the respondents whilst additional three-dimensional volume data were measured by 122/298 (41%) of the respondents. CMR volumes and CT volumes were used by 118/298 (40%) and 5/298 (2%) of respondents, respectively (Figure 2).

Assessment of LV systolic function was determined by two-dimensional Simpson's biplane ejection fraction by 264/297 (89%) of the respondents. Additional global longitudinal strain and

three-dimensional volumes were used by 155/297 (52%) and 126/297 (42%) of respondents, respectively. CMR and CT LV ejection fraction were measured by 143/297 (48%) and 12/297 (4%) of respondents, respectively.

### Aortopathy

In addition to transthoracic echocardiography, CMR, CT, and TEE were used to follow-up aortic dimensions by 80/296 (27%), 105/296 (35%), and 30/296 (10%) of respondents, respectively.

## Discussion

This is the first study to examine real-world practice regarding the assessment and quantification of AR. It demonstrates there is significant heterogeneity in the methods and techniques used to quantify AR and LV remodelling. CMR is commonly used as an adjunct when echocardiographic assessments are unclear.

### Grading AR severity

Qualitative grading of AR can be challenging. Visual jet area may underestimate severity of regurgitation due to eccentricity and can be influenced by colour Doppler gain.<sup>10</sup> Semi-quantitative pressure half-time is influenced by LV compliance.<sup>11</sup> The jet width to LV outflow tract diameter ratio may be difficult if there are multiple or eccentric jets. Our study found that the semi-quantitative vena contracta method was the most commonly used approach to assess AR severity, being employed routinely by 82% where initial visual assessment suggested moderate AR. However, there was a relatively low use of fully quantitative methods with the regurgitant volume or effective regurgitant orifice area used by only 57% of respondents. Detaint *et al.*<sup>7</sup> demonstrated that a quantitative approach for AR grading (using effective regurgitant orifice and regurgitant volume) was superior in identifying patients at high risk of poor outcome and therefore requiring surgery. A recent EACVI position paper recommends quantification using the proximal isovelocity surface area (PISA) methods if feasible.<sup>12</sup> There can be practical challenges as the PISA method may be difficult to measure due to interposition of valve tissue and difficulty in correctly identifying the flow convergence zone.<sup>12</sup> However training and practice to improve operator experience may improve feasibility, Detaint *et al.*<sup>7</sup> found that quantification was highly feasible and that regurgitant volume and effective orifice area could be quantified by 2 out of the 3 methods in 85% of their cohort.

Three-dimensional vena contracta has been shown to have better correlation to CMR quantification of AR than two-dimensional vena contracta particularly in patients with eccentric jets<sup>13</sup>; however, less than a quarter of respondents used this technique. This may be due in part to a lack of familiarity and training in the technique and the need for greater automation of measurements. In addition, dedicated post-processing software is required, which may limit access to the technique.

In this study, more respondents turned to CMR than TEE when echocardiographic windows were poor or there was discordance between clinical and echocardiographic findings. Routine CMR quantification was uncommon even though CMR quantification of AR demonstrates greater precision than echocardiographic methods.<sup>14</sup> The most common CMR quantification technique was phase-contrast assessment of regurgitant volume and fraction. However, this assumes the presence of laminar blood flow and that the imaging planes are aligned perpendicular to blood flow. Four-dimensional flow CMR was rarely used. Whilst representing an emerging technique it holds several important advantages, being potentially more accurate with eccentric jets as flow patterns and haemodynamics can be assessed along all three spatial dimensions and not being reliant on breath hold.<sup>15</sup>

### LV remodelling

AR leads to volume and pressure overload. Consequent LV dilatation is traditionally assessed on echocardiography using the two-dimensional (or M-mode) diameter at the base of the left ventricle (at the mitral valve tips).<sup>16</sup> However, measuring this parameter at the base of the left ventricle may not represent the true maximal diameter. Chetrit *et al.* showed that measuring the left ventricle at the maximal diameter (usually mid ventricle) correlates more closely with CMR volumes.<sup>17</sup> Our study shows a split with approximately half of respondents measuring the left ventricle at base and half at the maximal diameter. This will

potentially lead to heterogeneity in decision making with underestimation of LV dilatation and delayed referral for valve intervention in some patients. Given the importance of this measurement for deciding the timing of intervention in asymptomatic patients standardisation is required. Specific recommendations in guidelines and congress educational session would help reduce the variation.

In this study, 70% of respondents measured LV volumes with echocardiography, whilst 40% used CMR to assess LV remodelling and function. LV remodelling is not always symmetrical.<sup>18</sup> LV end-systolic volume ( $>45 \text{ mL/m}^2$ ) is a better predictor of outcome than diameter.<sup>5,19</sup> When TTE images are inadequate for obtaining accurate volumes, the use of echo contrast improves the accuracy and reproducibility.<sup>20</sup>

Global longitudinal strain is a marker of sub-clinical myocardial dysfunction and its impairment is associated with long term mortality.<sup>21</sup> Anand *et al.*<sup>22</sup> showed that global longitudinal strain was associated with high mortality in patients without class I or IIa recommendations for intervention, patients with at least two markers of LV dysfunction (ejection fraction  $<60\%$ , indexed end-systolic volume  $>45 \text{ mL/m}^2$  or global longitudinal strain worse than 15%).<sup>22</sup> In our study, 52% of respondents reported use of global longitudinal strain. This parameter may help guide timing of intervention in low risk asymptomatic cases with serial imaging showing these adverse features.

### Symptoms Testing

Determining symptom status can be challenging in some patients with severe AR. Patients may not complain of dyspnoea but may notice slow reductions in daily activities over time. In this study, 35% of respondents used exercise stress echocardiography and 15% of respondents used exercise testing to identify exercise-induced dyspnoea when symptom assessment was challenging or equivocal. Evaluation of LV contractile reserve can be identified during exercise stress echocardiography.<sup>23</sup> A lack of contractile reserve may identify latent dysfunction and post-aortic valve replacement LV impairment.<sup>24</sup> This was used in routine clinical practice by a third of the respondents.

### Limitations

This was an observational survey where participants were approached via a variety of different media (EACVI newsletters, social media and website) and therefore may be subject to selection bias. There is potential for recall bias when self-reporting data, which may impact recollection of perceived rather than actual practice. There was no external validation of the data provided by the participants. The sample size was relatively small, and the majority of participants were from Europe and worked in tertiary centres; therefore, the results may not reflect the full spectrum of practice.

## Conclusion

There is heterogeneity in TTE methods used to assess and quantify AR. The vena contracta is the most popular method with relative underutilisation of fully quantitative methods including the effective regurgitant orifice area and volume. CMR is commonly used when echocardiographic assessments are not clear. There is variation in the anatomical location to measure LV dilatation and variable use of LV volumes which may impact decision-making for intervention and requires specific recommendations in future guidelines.

### Consent

The study did not involve patient participation therefore no patient consent was obtained.

## Funding

None declared.

**Conflict of interest:** All authors have reported that they have no relationships relevant to the contents of this paper to disclose.

## Data availability

The data underlying this article will be shared on reasonable request to the corresponding author.

## Lead author biography



Dr Sanjeev Bhattacharyya is a consultant cardiologist & clinical lead for echocardiography at St Bartholomew's Hospital, London, UK and University College London Hospital. His main sub-specialty interests are valvular heart disease, heart failure and advanced echocardiography. His research interests are focussed on the application of multi-modality imaging to better characterize and identify the optimal timing of intervention in heart valve disease.

## References

- d'Arcy JL, Coffey S, Loudon MA, Kennedy A, Pearson-Stuttard J, Birks J et al. Large-scale community echocardiographic screening reveals a major burden of undiagnosed valvular heart disease in older people: the OxVALVE population cohort study. *Eur Heart J* 2016;**37**:3515–22.
- Bekeredjian R, Grayburn PA. Valvular heart disease: aortic regurgitation. *Circulation* 2005;**112**:125–34.
- Vahanian A, Beyersdorf F, Praz F, Milojevic M, Baldus S, Bauersachs J et al. 2021 ESC/EACTS guidelines for the management of valvular heart disease. *Eur Heart J* 2022;**43**:561–632.
- Yang LT, Michelena HI, Scott CG, Enriquez-Sarano M, Pislaru SC, Schaff HV et al. Outcomes in chronic hemodynamically significant aortic regurgitation and limitations of current guidelines. *J Am Coll Cardiol* 2019;**73**:1741–52.
- Anand V, Yang L, Luis SA, Padang R, Michelena HI, Tsay JL et al. Association of left ventricular volume in predicting clinical outcomes in patients with aortic regurgitation. *J Am Soc Echocardiogr* 2021;**34**:352–9.
- Zoghbi WA, Adams D, Bonow RO, Enriquez-Sarano M, Foster E, Grayburn PA et al. Recommendations for noninvasive evaluation of native valvular regurgitation: a report from the American society of echocardiography developed in collaboration with the society for cardiovascular magnetic resonance. *J Am Soc Echocardiogr* 2017;**30**:303–71.
- Detaint D, Messika-Zeitoun D, Maalouf J, Tribouilloy C, Mahoney DW, Tajik AJ et al. Quantitative echocardiographic determinants of clinical outcome in asymptomatic patients with aortic regurgitation: a prospective study. *JACC Cardiovasc Imaging* 2008;**1**:1–11.
- Lee JC, Branch KR, Hamilton-Craig C, Krieger EV. Evaluation of aortic regurgitation with cardiac magnetic resonance imaging: a systematic review. *Heart* 2018;**104**:103–10.
- Malahji M, Senapati A, Tayal B, Nguyen DT, Graviss EA, Nagueh S et al. Myocardial scar and mortality in chronic aortic regurgitation. *J Am Heart Assoc* 2020;**9**:e018731.
- Cape EG, Yoganathan AP, Weyman AE, Levine RA. Adjacent solid boundaries alter the size of regurgitant jets on Doppler color flow maps. *J Am Coll Cardiol* 1991;**17**:1094–102.
- Griffin BP, Flachskampf FA, Siu S, Weyman AE, Thomas JD. The effects of regurgitant orifice size, chamber compliance, and systemic vascular resistance on aortic regurgitant velocity slope and pressure half-time. *Am Heart J* 1991;**122**:1049–56.
- Lancellotti P, Pibarot P, Chambers J, La Canna G, Pepi M, Dulgheru R et al. Multi-modality imaging assessment of native valvular regurgitation: an EACVI and ESC council of valvular heart disease position paper. *Eur Heart J Cardiovasc Imaging* 2022;**23**:e171–232.
- Ewe SH, Delgado V, van der Geest R, Westenberg JJ, Haecck ML, Witkowski TG et al. Accuracy of three-dimensional versus two-dimensional echocardiography for quantification of aortic regurgitation and validation by three-dimensional three-directional velocity-encoded magnetic resonance imaging. *Am J Cardiol* 2013;**112**:560–6.
- Cawley PJ, Hamilton-Craig C, Owens DS, Krieger EV, Strugnell WE, Mitsumori L et al. Prospective comparison of valve regurgitation quantitation by cardiac magnetic resonance imaging and transthoracic echocardiography. *Circ Cardiovasc Imaging* 2013;**6**:48–57.
- Gorecka M, Bissell MM, Higgins DM, Garg P, Plein S, Greenwood JP. Rationale and clinical applications of 4D flow cardiovascular magnetic resonance in assessment of valvular heart disease: a comprehensive review. *J Cardiovasc Magn Reson* 2022;**24**:49.
- Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American society of echocardiography and the European association of cardiovascular imaging. *J Am Soc Echocardiogr* 2015;**28**:1–39.e14.
- Chetrit M, Roujol S, Picard MH, Timmins L, Manning WJ, Rudski LG et al. Optimal technique for measurement of linear left ventricular dimensions. *J Am Soc Echocardiogr* 2019;**32**:476–83.e1.
- Dujardin KS, Enriquez-Sarano M, Rossi A, Bailey KR, Seward JB. Echocardiographic assessment of left ventricular remodeling: are left ventricular diameters suitable tools? *J Am Coll Cardiol* 1997;**30**:1534–41.
- Hashimoto G, Enriquez-Sarano M, Stanberry LI, Oh F, Wang M, Acosta K et al. Association of left ventricular remodeling assessment by cardiac magnetic resonance with outcomes in patients with chronic aortic regurgitation. *JAMA Cardiol* 2022;**7**:924–33.
- Thomson HL, Basmadjian AJ, Rainbird AJ, Razavi M, Avierinos JF, Pellikka PA et al. Contrast echocardiography improves the accuracy and reproducibility of left ventricular remodeling measurements: a prospective, randomly assigned, blinded study. *J Am Coll Cardiol* 2001;**38**:867–75.
- Alashi A, Mentias A, Abdallah A, Feng K, Gillinov AM, Rodriguez LL et al. Incremental prognostic utility of left ventricular global longitudinal strain in asymptomatic patients with significant chronic aortic regurgitation and preserved left ventricular ejection fraction. *JACC Cardiovasc Imaging* 2018;**11**:673–82.
- Anand V, Michelena HI, Scott CG, Lee AT, Rigolin VH, Pislaru SV et al. Echocardiographic markers of early left ventricular dysfunction in asymptomatic aortic regurgitation: is it time to change the guidelines? *JACC Cardiovasc Imaging* 2025;**18**:266–74.
- Badiani S, Waddingham P, Lloyd G, Bhattacharyya S. Stress echocardiography in valvular heart disease. *Expert Rev Cardiovasc Ther* 2018;**16**:795–804.
- Wahi S, Haluska B, Pasquet A, Case C, Rimmerman CM, Marwick TH. Exercise echocardiography predicts development of left ventricular dysfunction in medically and surgically treated patients with asymptomatic severe aortic regurgitation. *Heart* 2000;**84**:606–14.